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PREFACE

The National Ecology Research Center of the U.S. Fish and Wildlife Service (FWS) is supporting a series of field research studies to document relationships between hydric soils and wetland vegetation in selected wetlands throughout the United States. This research program is a continuation of the FWS effort, begun by Wentworth and Johnson (1986), to develop a procedure to identify wetlands based on the indicator status of vegetation as described in the FWS National List of Plant Species that Occur in Wetlands (Reed 1987). This list places vascular plants into one of five categories according to their frequency of occurrence in wetlands. Concurrent with the development of the wetland plant list, the U.S. Soil Conservation Service (SCS) developed a list of soils, entitled Hydric Soils of the United States (SCS 1985). Studies supported by the National Ecology Research Center compare associations of plant species, described quantitatively using the Wentworth and Johnson (1986) procedure, with the hydric status of soils according to the SCS hydric soils list.

These studies were conceived in 1984 and initiated in 1985 in response to internal planning efforts of the FWS. They parallel ongoing efforts by the SCS to delineate wetlands for Section 1221 of the Food Security Act of 1985 (the "Swampbuster" provision). The SCS and FWS jointly provided direction in the development of the Wentworth and Johnson (1986) procedure, and the SCS is currently testing a method that combines hydric soils with the Wentworth and Johnson procedure for practical wetland delineation. The efforts of the two agencies are complementary and are being conducted in close cooperation.

The primary objectives of the FWS studies are to (1) assemble a quantitative data base of wetland plant community composition for determining the relationship between wetland plants and hydric soils; (2) test various delineation algorithms based on the indicator status of plants against independent measures of hydric character, primarily hydric soils; and (3) in some instances, relate wetland plants and hydric soils to groundwater hydrology. The results of these studies also can be used, with little or no supplementary hydrologic information, to compare wetland delineation methods of the U.S. Army Corps of Engineers (Environmental Laboratory 1987) and the U.S. Environmental Protection Agency (Sipple 1987).

Moisture gradient research at the University of Rhode Island (URI) was initiated in 1984 with support from the U.S. Army Engineer Waterways Experiment Station and the Rhode Island Agricultural Experiment Station. During 1985 and 1986, field data on soils, vegetation, and hydrology were gathered at the three forested wetlands described in this report. In 1987 the National Ecology Research Center provided the URI research team with

supplementary funds for collection of a third year's water level data, analysis of vegetation data using the Wentworth and Johnson (1986) procedure, and soil-vegetation correlations. This report presents the findings of the research supported by the FWS.

Any questions or suggestions regarding the FWS moisture gradient studies should be directed to: Charles Segelquist, U.S. Fish and Wildlife Service, 2627 Redwing Road, Creekside One Building, Fort Collins, CO 80526-2899; FTS 323-5384 or Commercial (303) 226-9384.

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ACKNOWLEDGMENTS

The U.S. Army Engineer Waterways Experiment Station, under Contract No. DACW39-84-C-0065, funded the collection and analysis of soils data and hydrologic measurements during 1985 and 1986. The Rhode Island Agricultural Experiment Station (RIAES), through McIntire-Stennis Project No. 961, sponsored the collection of all vegetation data, as well as some of the hydrologic research.

The Rhode Island Moisture Gradient Study (FPTO 85-61) was supervised by Gerald Horak, Program Manager at TGS Technology, Inc., Fort Collins, CO, under FWS Contract No. 14-16-0009-85-001. Charles Segelquist of the National Ecology Research Center was Project Officer.

We would like to express our gratitude to Paul and Mary Daley of West Kingston, RI, for permission to establish two research sites on their property. Thanks are extended also to the Rhode Island Department of Environmental Management for allowing us to locate a third site in the Great Swamp Management Area. William Wright and Arthur Gold, of URI's Department of Natural Resources Science (NRS), provided valuable advice on project design as well as soils and hydrologic analyses. William DeRagon, also of NRS, prepared the original draft of Figure 2. Helpful comments on a preliminary draft of this report were provided by Charles Segelquist, William Slauson, and Lewis Cowardin of the FWS, and Robert Franzen and Stephen Brady of the SCS. Finally, we thank Mary Salerno of the NRS Department for typing the various drafts of this report.

This report is RIAES Contribution No. 2456.

INTRODUCTION

The decline in the quality and quantity of wetland resources is receiving broad national recognition from both the scientific and resource management communities. Wetlands have been defined by the U.S. Fish and Wildlife Service (FWS) as "lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water" (Cowardin et al. 1979:3). While scientists attempt to understand the physical, chemical, and biological processes that characterize wetlands, resource management agencies are faced with the task of developing management strategies for, and controlling impacts to, wetlands. Wetland regulations require that boundaries be drawn between wetland and nonwetland, even though such legal boundaries may have little ecological significance. The zone extending from wetland into the adjoining upland, where components of both communities can be found, is commonly referred to as the "transition zone"; the regulatory boundary is assumed to lie somewhere within this zone.

The three most basic identifying features of wetlands are hydrology, soils, and vegetation. Hydrology is generally recognized as the driving force that maintains wetland conditions, but it is also the most difficult parameter to describe, due to seasonal, annual, and longer-term fluctuations. As a result, increased attention has been focused on soil and vegetation characteristics as indirect measures of hydrology. However, there have been few attempts to correlate the three basic parameters for the purpose of wetland identification, and it will likely be many years before such correlations have been achieved in even a small number of wetland types.

In the meantime, resource management agencies need expeditious, objective, ecologically sound methods of wetland delineation. At the present time, the various Federal agencies involved in wetland management have slightly different criteria for identifying and delineating wetlands. The U.S. Army Corps of Engineers (CE) has taken a multiparameter approach, requiring positive evidence of wetland hydrology, vegetation, and soils (Environmental Laboratory 1987). The U.S. Environmental Protection Agency (EPA) accepts dominant obligate wetland plant species as adequate evidence of wetland conditions (Sipple 1987); the EPA requires soil and hydrologic measures for confirmation when the vegetation is facultative (i.e., not clearly wetland or upland). The FWS, which also addresses hydrology, vegetation, and soils, requires that wetland criteria be met for least one of these three basic features (Cowardin et al. 1979).

To facilitate the identification of wetlands and their boundaries, the FWS has compiled the <u>National List of Plant Species that Occur in Wetlands</u> (Reed 1987) and classified each species according to its frequency of

occurrence in wetlands. The indicator categories are: Obligate Wetland, greater than 99% frequency; Facultative Wetland, 67%-99%; Facultative, 34%-66%; Facultative Upland, 1%-33%; and Obligate Upland, less than 1%. Toward the same end, the U.S. Soil Conservation Service has developed a list entitled Hydric Soils of the United States (SCS 1985). Each soil series in this list is designated hydric according to clearly defined criteria. Together, the lists of soils and plants provide an operational definition of wetland under the Cowardin et al. (1979) classification system, and they also provide substantial technical support for State and Federal regulatory programs.

At present, multiparameter approaches to wetland delineation yield approximate results at best because the relationships among the three parameters have not been fully described. This report is part of a national effort by the FWS to compare wetland designations based on weighted and index averaging techniques (Wentworth and Johnson 1986), which employ the indicator categories of the FWS plant list, with designations based on the hydric status of soils. This study, conducted in three deciduous forested wetlands in southern Rhode Island, had the following specific objectives:

- to test agreement between the hydric status of soils and both weighted and index averages calculated for individual life form layers of vegetation,

- to evaluate the 3.0 wetland/upland vegetation breakpoint proposed by Wentworth and Johnson (1986),

- to compare the results of weighted and index averaging,

- to compare weighted averaging results based on different species importance measures, and

- to assess the potential utility of weighted and index averaging for wetland boundary identification.

LITERATURE REVIEW

Relationships between wetland vegetation and water regimes have been described in a number of basic ecological studies of forested river floodplains. Frye and Quinn (1979) found that water table depth was highly correlated with the distribution of woody vegetation along the Raritan River in New Jersey. The forest overstory on a Sangamon River floodplain in Illinois was shown to vary in species richness, diversity, evenness, and dominance in response to flooding frequency (Bell 1980). On a Mississippi River floodplain in the same State, Robertson et al. (1978) segregated vegetation plots by depth of flooding along an elevational gradient.

Soil morphology and chemistry also have been related to wetland hydrology or vegetation in several studies. Pickering and Veneman (1984) correlated soil mottle formation and coloration with water table depth and fluctuation in a Massachusetts hydrosequence. Bigler and Richardson (1984) were able to relate deep-marsh soil characteristics to the dominant plant species in prairie pothole wetlands in North Dakota.

A few studies have correlated all three parameters, but with varying success. In a study of forested wetlands in eastern Connecticut, Anderson et al. (1980) found that, while the water content of the soil along transects running from wetland to upland was variable, there was generally an inverse relationship between soil acidity and soil moisture content. These authors also were able to group vegetation into broad frequency distributions related to soil moisture and ground elevation. Sanville et al. (1986) identified consistent trends in relationships between soil moisture and soil characteristics such as oxidation-reduction potential and pH, but found correlations between vegetation and physical data to be inconsistent. Paratley and Fahey (1986) found that soil moisture correlated well with both soil morphology and vegetation in forested wetlands in New York. The key hydrologic features in their study were the mean depth of the water table and the duration of the summer drawdown.

Vegetation often has been the primary focus of research on wetland boundary placement. In attempting to define the upper limit of salt marshes on the U.S. West Coast, Eilers et al. (1983) found the results of six methods of vegetation analysis to be in "close" agreement. A similar study by Zedler and Cox (1985) tested five methods of boundary placement in a salt marsh in California and found that the upper limit of the marsh was consistently located within a band spanning 2 dm in elevation. Both studies concluded that species frequency data yielded comparable results to more sampling-intensive percent cover data. They also agreed that quantifying physical and edaphic parameters such as slope and soil moisture could facilitate delineation in broader, less abrupt transition zones. This conclusion was

supported by Roman et al. (1985), who applied exploratory statistics to soil, vegetative, and hydrologic data from New Jersey Pinelands wetlands and found that, while vegetation trends were evident, vegetation alone was insufficient to separate transition zones from wetland zones.

Recently there has been increased interest in using the National List of Plant Species that Occur in Wetlands (Reed 1987) to standardize wetland identification and delineation. In an effort to make the process more objective and quantitative, Michener (1983) assigned numerical indices to the five indicator categories in the FWS plant list for use in the calculation of weighted averages. Weighted averaging takes into account the relative importance of each species in a sample. Indices ranged from 0 to 1, with higher values indicating more frequent occurrence in wetlands. Wentworth and Johnson (1986) established a different set of indices, ranging from 1 for Obligate Wetland species to 5 for Obligate Upland species, and they tested several variations of weighted averaging and index averaging on four existing data sets from different geographic regions of the U.S. Index averaging takes into account species presence, but not relative importance. They found that weighted averaging results correlated well with independently derived designations of vegetation stands or types along moisture gradients and that index averages closely agreed with weighted averages. Wentworth and Johnson proposed that the breakpoint between wetland and upland should be 3.0 on this scale, but cautioned that a "gray zone" between 2.5 and 3.5 should be recognized where vegetation alone might not be sufficient to identify wetland conditions.

Adams et al. (1987) used the FWS indicators to compare boundaries determined by CE criteria (Sanders et al. 1984) with boundaries determined by an SCS methodology in three wetland types in North Carolina. The CE method considered wetlands to be those stands with at least 50% of the dominant species occurring in the Obligate Wetland, Facultative Wetland, and Facultative categories. The SCS method employed a "Prevalence Index," which incorporated Wentworth and Johnson's numerical indices, and a 3.00 breakpoint (51 Federal Register 23507; June 27, 1986). The SCS method was developed for implementation of the "Swampbuster" provisions of the Food Security Act of 1985. Adams et al. (1987) concluded that there was little difference between the locations of wetland boundaries identified by the CE and SCS methods, but that elimination of Facultative species from the analysis brought vegetation, hydrographic, and soils indicators of wetland into much closer agreement.

Wentworth and Johnson's weighted averaging approach also has been used to designate wetland, transition, and upland zones in the Great Dismal Swamp of Virginia and North Carolina (Carter et al. 1988). In that study, sample plots with vegetation scores below 2.5 were classified as wetland, from 2.5 to 3.5 as transition, and above 3.5 as upland. The resulting transition zones were very broad, leading the authors to conclude that averaging techniques may be useful in defining the transition zone, but that data on soils and hydrology may be needed before a wetland boundary can be drawn.

Two recent moisture gradient studies have correlated weighted and index averages for vegetation with hydric soil status as designated by Hydric Soils of the United States (SCS 1985). Dick-Peddie et al. (1987) calculated

weighted and index averages, using Wentworth and Johnson's 1-to-5 scale, for two forested riparian communities in New Mexico. They found both weighted and index averaging results to correlate closely with the hydric status of the soils. Erickson and Leslie (1987) applied weighted averaging, using Michener's 0-to-1 scale and Wentworth and Johnson's 1-to-5 scale, as well as index averaging to the "groundcover" layer in two Nebraska wetlands. Their results indicated that weighted averages based on Wentworth and Johnson's scale were not significantly different from index averages. Using a 3.0 breakpoint, vegetation scores showed strong agreement with hydric soil status in the Nebraska study.

METHODS

STUDY SITE CRITERIA

Three forested sites in southern Rhode Island were selected for study, using the following criteria:

- continuous canopy of broad-leaved deciduous trees in both wetland and adjacent upland,
- freedom from disturbance for at least 40 years,
- gradual slope from wetland to upland,
- stratified surficial geologic deposits, and
- soils of the same drainage toposequence, including very poorly drained, poorly drained, somewhat poorly drained, and moderately well drained soils, as defined by Wright and Sautter (1979).

The three sites were named Laurel Lane 1 (LL1), Laurel Lane 2 (LL2), and Great Swamp (GSW). The Laurel Lane sites, located in South Kingstown, were within 200 m of each other and drained by the same small perennial stream. The Great Swamp site was situated 4.3 km from the others, in the Richmond portion of the State-owned Great Swamp Management Area.

SAMPLING DESIGN

At each site, three parallel line transects extending from wetland to upland were established at 15-m intervals. Along each transect, six sampling stations were located by soil drainage class and elevation. Station 1 was placed at the lowest end of each transect in very poorly drained soil. Station 3 was placed at the boundary between poorly and very poorly drained soils. Station 2 was then located at the elevational midpoint between Stations 1 and 3. Stations 4, 5, and 6 were placed approximately in the middle of poorly drained, somewhat poorly drained, and moderately well drained soil zones, respectively.

Groundwater levels were monitored to provide an independent measure of site wetness. At each station, a capped water table well constructed of 3.8-cm, perforated PVC pipe was installed to a depth ranging from 1.5 m to 3.0 m, depending on the station. At LL1, four thermocouples also were installed at each station, one at each of four depths: 15 cm, 30 cm, 45 cm, and 60 cm (Figure 1). During the growing season, defined by SCS (1985) as

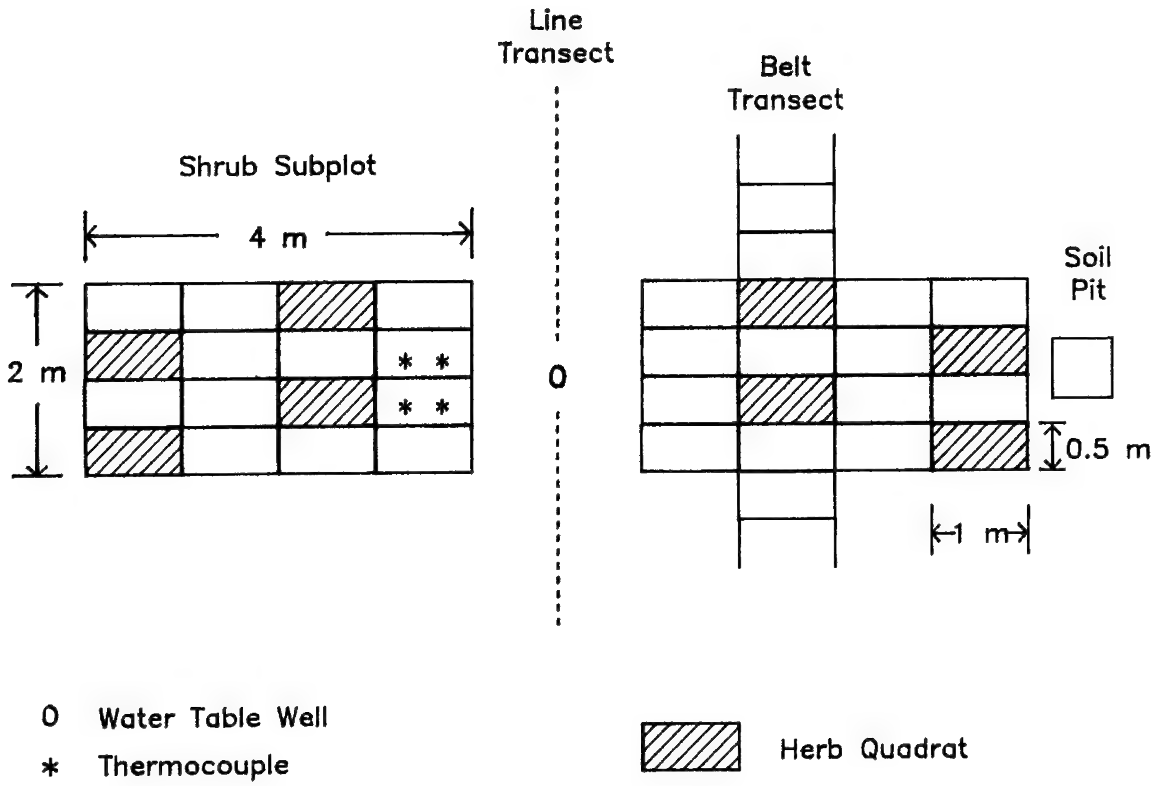

Figure 1. Sampling design at individual stations.

that period having soil temperatures above biologic zero (5 °C), groundwater levels and soil temperatures were measured weekly. During the remainder of the year, measurements were taken biweekly. Data collection began in May 1985 and continued through November 1987.

Shrub and herb layer vegetation were sampled both at individual stations and along a continuous belt running the length of each transect. Station data provided the basis for soil-vegetation correlations and for comparison with hydrologic measurements. The continuous belts were employed (1) to give a more complete picture of the variation in vegetation throughout the moisture gradient, and (2) to permit evaluation of weighted and index averaging as possible methods for identifying wetland regulatory boundaries.

Two 2x4-m shrub subplots were located at each station (Figure 1). The subplots were placed on either side of the water table well with their long axes perpendicular to the transect. A travel lane 1.5 m wide between the two subplots permitted travel along the transect without disturbing the plots. Shrubs, defined as woody plants from 0.5 to 6 m in height, were sampled in two height classes, tall shrubs (2-6 m) and low shrubs (0.5-2 m). Stem density and percent cover data were obtained for each shrub species in each subplot. Percent cover was estimated to the nearest 5%, or if less than 5%, to the nearest 1%. Species with less than 1% cover were assigned a cover value of 0.5%. To sample the herb layer, which consisted of vascular nonwoody species, Sphagnum mosses, and woody plants less than 0.5 m in

height, four 0.5x1-m quadrats were systematically placed within each of the shrub subplots (Figure 1). Percent cover was estimated using the same cover classes as for the shrubs.

A belt transect 1 m wide was located parallel to, and 1.75 m away from, each line transect so that it passed through one subplot at each station (Figure 1). Within each belt, shrub and herb layer vegetation were sampled in 0.5x1-m contiguous quadrats. Stem density was recorded for shrubs in one height class (0.5-6 m), while herbs were sampled in the same manner as at the stations.

Trees (woody plants at least 6 m in height) were sampled in a 10-m wide belt centered on each line transect. Data collected included species, diameter at breast height (dbh), and location within the belt.

A soil pit was excavated adjacent to one of the shrub subplots at each station, at approximately the same elevation as the water table well (Figure 1). Where high water levels and unstable soils inhibited pit excavation, soil profiles were described from auger samples. Soils were described using standard procedures (Soil Survey Staff 1951) and classified at the series level. The hydric status of each series was determined from <u>Hydric Soils of the United States</u> (SCS 1985).

Using a transit, the relative elevation of the ground surface was determined at all water table wells, station subplots, and belt quadrats, and at the base of each tree within the tree belts. Species nomenclature follows the <u>National List of Scientific Plant Names</u> (SCS 1982).

DATA ANALYSIS

Percent cover values and stem densities were converted to relative values to permit comparison of species abundance among sample plots (Mueller-Dombois and Ellenberg 1976). Shrub data from the two subplots at each station were combined, as were percent cover estimates from the eight herb quadrats at each station. In the belt transect analyses, shrub layer data for each pair of quadrats were pooled, producing 1-m^2 contiguous plots. Herb layer data were analyzed by individual 0.5x1-m quadrats. Because of the close spacing of transects and the proximity of adjacent stations on the steeper slopes, establishment of standard 100-m^2 sample plots for trees (Mueller-Dombois and Ellenberg 1976) was not possible. Instead, tree "plots" of 10-m width and varying length were created by grouping trees that occurred within each soil drainage class. The boundaries of the drainage classes were approximated from the elevations of adjacent stations representing different drainage classes. Even using this approach, several tree plots covered less than 100 m^2. Table 1 presents a synopsis of the vegetation sampling design by life form layer.

Weighted and index averaging calculations followed Wentworth and Johnson (1986). Each species was assigned the Region 1 indicator status given in the <u>National List of Plant Species that Occur in Wetlands</u> (Reed 1987). Numerical indices were assigned to the indicator categories as follows: Obligate

Table 1. Vegetation sampling design by life form layer.

Sampling method	Life form layer	Sampled area	Importance measures
Station	Tall shrub (2-6 m)	16 m^2 (two 2x4-m subplots)	Stem density, percent cover
	Low shrub (0.5-2 m)	16 m^2 (two 2x4-m subplots)	Stem density, percent cover
	Herb[a]	4 m^2 (eight 0.5x1-m quadrats)	Percent cover
Belt transect	Tree (≥ 6 m)	Soil drainage class boundaries x 10 m wide	Stem density, basal area
	Shrub (0.5-6 m)	1 m^2 (two contiguous 0.5x1-m quadrats)	Stem density
	Herb[a]	0.5 m^2 (contiguous 0.5x1-m quadrats)	Percent cover

[a]Includes all vascular nonwoody species regardless of height, Sphagnum mosses, and woody plants less than 0.5 m tall.

Wetland (OBL) = 1, Facultative Wetland (FACW) = 2, Facultative (FAC) = 3, Facultative Upland (FACU) = 4, and Obligate Upland (UPL) = 5. Species that were not in the list and not under consideration for inclusion in the list (P.B. Reed, FWS, St. Petersburg, FL; pers. comm., 1988) were classified as UPL. The remaining unclassified species were excluded from analysis, as were plants that could be identified to genus only. The genus Sphagnum, an important wetland indicator in the Northeast, was considered OBL even though it and other nonvascular plants were not included in the FWS plant list. We changed the classification of swamp azalea (Rhododendron viscosum) from OBL to FACW, since we believe that this is clearly not an OBL species in southern Rhode Island. Appendix A includes species found at one or more of the three study sites, along with the FWS indicator status for each.

The weighted averaging formula, taken from Wentworth and Johnson (1986), is:

$$W_j = (\sum_{i=1}^{p} I_{ij} E_i)/(\sum_{i=1}^{p} I_{ij})$$

where W_j = weighted average for sample plot j

I_{ij} = importance value for species i in plot j

E_i = ecological index for species i

p = number of species in sample plot j

Several importance measures were employed for the various plant life forms. In the tree stratum, weighted averages were calculated from stem density and from basal area. At the individual stations, weighted averages for shrubs were calculated from stem density and from percent cover. Weighted averages for shrub belt quadrats were based on stem density. All herb layer calculations were based on percent cover.

Index averages were calculated from presence/absence information derived from density data in the tree and shrub layers, and from percent cover data in the herb layer. Calculations were made according to the following formula, which also was taken from Wentworth and Johnson (1986):

$$I_j = (\sum_{i=1}^{p} E_i)/p$$

where I_j = index average for sample plot j

E_i = ecological index for species i

p = number of species in sample plot j

Differences between the scores of hydric and nonhydric soil stations at each site were examined using two-sample t-tests. Paired-sample t-tests were used when comparing the results of weighted averages derived from different importance measures, and when testing for differences between weighted averages and index averages. Significance levels for all statistical tests were set at 5% ($p<0.05$). The null hypothesis in all cases was that there was no significant difference between the populations sampled (i.e., two-tailed test).

In interpretation of results, samples with weighted or index averages below 3.00 were considered wetland, while samples with averages above 3.00 were considered upland. Scores of exactly 3.00 were regarded as inconclusive in belt transect analyses, but for the purpose of establishing a wetland/upland breakpoint using station data, samples scoring 3.00 were included in the wetland category.

RESULTS

TOPOGRAPHY

Topographic profiles of the transects, constructed from the relative elevations of the belt quadrats, appear in Figure 2. The most gradual slopes occurred at GSW where the change in elevation along the length of each transect was about 1 m. At the Laurel Lane sites, the change in elevation ranged from 1.5 m to 2 m, with the steepest slopes occurring at LL2. At all sites, there was relatively little change in elevation between Stations 1 and 3; most of the rise occurred between Stations 3 and 6.

SOILS

The moderately well drained (MWD), somewhat poorly drained (SPD), and poorly drained (PD) soils at the three study sites were predominantly sandy, weakly developed Entisols. At the very poorly drained (VPD) stations, the soils were either Histosols or Inceptisols with histic epipedons. The typical drainage toposequence consisted of the Deerfield (MWD), Wareham (SPD/PD), and Scarboro (VPD) series (Tables 2-4). The very poorly drained Adrian and Carlisle series, both Histosols, occurred at LL1 and LL2. The Sudbury (MWD) and Walpole (PD) series, of the order Inceptisols, were found at individual stations at GSW and LL1, respectively.

According to the national list of hydric soils (SCS 1985), all of the very poorly drained and poorly drained soils were hydric, while the somewhat poorly drained and moderately well drained soils--except for one SPD Wareham soil at LL2--were nonhydric (Tables 2-4). In the remainder of this report, the terms "hydric" and "nonhydric" refer to the criteria and series designations given in the national list.

An inspection of soil temperature data revealed that temperatures were at or above 5 °C from roughly mid-April through the end of November. In all of the soils and hydrologic analyses that follow, the growing season was thus considered to extend from 15 April through 30 November.

HYDROLOGY

The moisture gradient from wetland to upland is clearly reflected in the relative position of the water table between Stations 1 and 6 on each transect (Figure 2). At all sites, Station 1 had the highest relative water level, and the depth to the mean water level increased steadily between Stations 3 and 6.

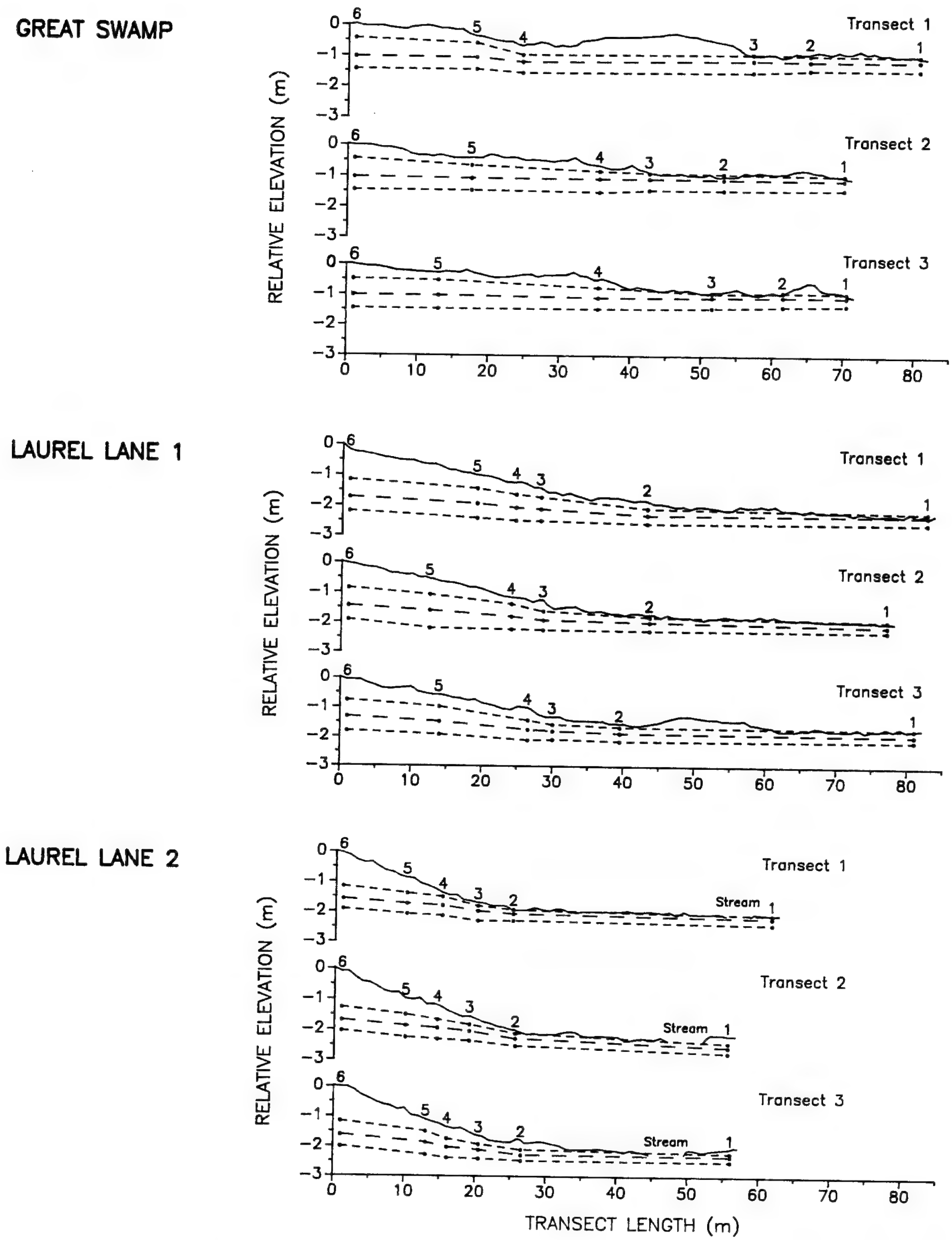

Figure 2. Topographic profiles showing station locations and maximum, minimum, and mean water levels calculated from weekly measurements over three growing seasons.

Table 2. Drainage class, soil series, and hydric status for each sampling station at Great Swamp.

Transect	Station	Drainage class[a]	Soil series	Hydric status[b]
1	6	MWD	Sudbury	NH
	5	SPD	Deerfield	NH
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Scarboro	H
	1	VPD	Scarboro	H
2	6	MWD	Deerfield	NH
	5	PD	Wareham	H
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Scarboro	H
	1	VPD	Scarboro	H
3	6	MWD	Deerfield	NH
	5	PD	Wareham	H
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Scarboro	H
	1	VPD	Scarboro	H

[a]Determined by soil morphology; MWD = moderately well drained, SPD = somewhat poorly drained, PD = poorly drained, VPD = very poorly drained.
[b]From Hydric Soils of the United States (SCS 1985); H = hydric, NH = nonhydric.

Detailed water level characteristics for the 54 stations are presented by site in Table 5. Mean water levels are based on weekly measurements taken throughout the three growing seasons. Data on the percentage of the growing season during which the water level was within 30 cm of the ground surface also are provided because the duration of soil saturation directly influences soil morphology (Zobeck and Ritchie 1984, Evans and Franzmeier 1986) and plant species distribution (Huffman and Forsythe 1981, Paratley and Fahey 1986). Examination of soil profiles indicated that the great bulk of tree, shrub, and herb roots was within 30 cm of the surface.

While mean water levels at Stations 2-6 were consistently nearer the surface at GSW than at the other sites, the ranges of mean water levels among the hydric stations varied little with site. At GSW, the hydric stations had mean water levels ranging from -9.1 to -74.2 cm, while mean water levels at the nonhydric stations ranged from -74.7 to -105.2 cm. At LL1, mean water

Table 3. Drainage class, soil series, and hydric status for each sampling station at Laurel Lane 1.

Transect	Station	Drainage class[a]	Soil series	Hydric status[b]
1	6	MWD	Deerfield	NH
	5	SPD	Deerfield	NH
	4	PD	Wareham	H
	3	PD	Wareham	H
	2	VPD	Scarboro	H
	1	VPD	Adrian	H
2	6	MWD	Deerfield	NH
	5	SPD	Deerfield	NH
	4	PD	Wareham	H
	3	PD	Wareham	H
	2	VPD	Scarboro	H
	1	VPD	Scarboro	H
3	6	MWD	Deerfield	NH
	5	SPD	Deerfield	NH
	4	PD	Walpole	H
	3	PD	Wareham	H
	2	VPD	Scarboro	H
	1	VPD	Scarboro	H

[a]Determined by soil morphology; MWD = moderately well drained, SPD = somewhat poorly drained, PD = poorly drained, VPD = very poorly drained.
[b]From Hydric Soils of the United States (SCS 1985); H = hydric, NH = nonhydric.

levels at the hydric stations ranged from -16.8 to -75.9 cm, and, at the nonhydric stations, from -88.3 to -149.8 cm. LL2 had the deepest mean water levels, ranging from -12.0 to -82.1 cm at the hydric stations and from -82.1 to -161.6 cm at the nonhydric stations. Although there was no overlap in mean water levels between hydric and nonhydric stations within sites, overlap among sites did occur in two instances. The driest hydric stations at LL1 and LL2 had lower mean water levels (-75.9 and -82.1 cm, respectively) than the wettest nonhydric station at GSW (-74.7 cm).

The water table was within 30 cm of the ground surface less than 2% of the time at all of the nonhydric stations. At the hydric stations, the duration ranged from 0% to 95% of the time. At all sites, Station 1 water levels were within 30 cm of the surface during at least 90% of the measurements recorded over the three growing seasons.

Table 4. Drainage class, soil series, and hydric status for each sampling station at Laurel Lane 2.

Transect	Station	Drainage class[a]	Soil series	Hydric status[b]
1	6	MWD	Deerfield	NH
	5	SPD	Wareham	H
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Adrian	H
	1	VPD	Carlisle	H
2	6	MWD	Deerfield	NH
	5	SPD	Deerfield	NH
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Scarboro	H
	1	VPD	Carlisle	H
3	6	MWD	Deerfield	NH
	5	SPD	Deerfield	NH
	4	PD	Wareham	H
	3	VPD	Scarboro	H
	2	VPD	Adrian	H
	1	VPD	Carlisle	H

[a]Determined by soil morphology; MWD = moderately well drained, SPD = somewhat poorly drained, PD = poorly drained, VPD = very poorly drained.
[b]From Hydric Soils of the United States (SCS 1985); H = hydric, NH = nonhydric.

Monthly precipitation levels for the study period are presented in Table 6. Annual precipitation was roughly equal to the 30-yr mean in 1985, slightly above the mean in 1986, and slightly below the mean in 1987. The distribution of precipitation within each of the three years varied widely, however. Growing-season precipitation was considerably above normal in 1985, near normal in 1986, and considerably below normal in 1987. Rainfall for May-July of 1987 was the lowest in 22 years (U.S. Dept. Commerce, National Weather Service records, T.F. Green Airport, Warwick, RI).

VEGETATION

One hundred two species were found at the three sites (Appendix A); 48 were woody and 54 herbaceous. When grouped by FWS indicator status (Reed 1987), 22 species were found to be Obligate Wetland, 30 were Facultative Wetland, 14 were Facultative, 23 were Facultative Upland, and 6 were Obligate

Table 5. Growing season water level characteristics of the three study sites. Stations with hydric soils are designated by the symbol H; all other stations are nonhydric.

Tran	Sta	GSW Mean water level[a] (cm)		GSW WT≤30[b] (%)	LL1 Mean water level (cm)		LL1 WT≤30 (%)	LL2 Mean water level (cm)		LL2 WT≤30 (%)
1	6	-103.0		1.2	-149.8		0	-150.9		0
	5	-74.7		1.2	-88.3		1.2	-82.1	H	0
	4	-42.5	H	15.4	-75.9	H	1.2	-53.8	H	8.9
	3	-20.2	H	81.3	-63.1	H	8.2	-33.2	H	52.4
	2	-15.7	H	90.4	-38.9	H	29.6	-18.6	H	89.9
	1	-10.6	H	91.5	-16.9	H	93.1	-12.0	H	93.2
2	6	-105.2		1.2	-139.7		0	-161.6		0
	5	-66.6	H	2.5	-96.0		0	-89.0		0
	4	-40.1	H	31.6	-61.5	H	7.8	-66.7	H	0
	3	-19.1	H	81.3	-46.2	H	15.6	-40.8	H	26.3
	2	-15.6	H	87.3	-22.2	H	82.2	-33.3	H	43.2
	1	-10.1	H	92.7	-20.7	H	86.6	-17.3	H	87.6
3	6	-105.2		0	-128.9		0	-155.1		0
	5	-74.2	H	1.2	-90.3		1.2	-82.1		0
	4	-59.8	H	2.5	-62.7	H	3.5	-68.5	H	0
	3	-14.4	H	90.4	-46.5	H	10.9	-39.9	H	26.1
	2	-14.7	H	90.4	-27.8	H	71.0	-30.0	H	61.7
	1	-9.1	H	91.7	-16.8	H	92.3	-12.3	H	94.6

[a]Calculated from weekly measurements over three growing seasons (n = 91-93).
[b]Percent of time water table was within 30 cm of ground surface.

Upland. Excluded from further analyses were seven species for which the FWS indicator status was undetermined.

Species richness differed slightly among the three sites: 77 species were present at GSW, 61 at LL1, and 59 at LL2; six, five, and three species, respectively, were excluded from analysis. Table 7 depicts the distribution of species by FWS indicator status in the four life form layers at each site. Species richness declined markedly with increasing height of life form layers.

Tree Layer

Red maple (*Acer rubrum*) dominated both density and basal area figures in the very poorly and poorly drained soil zones at all sites, while white oak (*Quercus alba*) was the dominant species in the somewhat poorly and moderately

Table 6. Precipitation levels (cm) for the study period compared to the 30-year (1951-1980) average. All precipitation data collected at the URI weather station, Kingston, RI.

Month	30-yr mean	1985	1986	1987
Jan	10.74	2.59	14.91	15.72
Feb	9.37	4.19	8.66	2.31
Mar	11.81	9.96	8.56	12.93
Apr	10.49	3.07	5.51	20.98
May	10.46	14.88	4.95	4.60
Jun	7.42	11.96	10.92	3.71
Jul	7.59	7.39	16.79	2.67
Aug	11.33	32.28	10.62	8.00
Sep	10.44	6.99	2.34	15.52
Oct	10.06	6.27	6.88	6.02
Nov	11.81	23.39	20.60	9.63
Dec	11.63	2.54	24.84	8.91
Annual total	123.15	125.41	135.58	111.00
Growing-season[a] total	73.73	103.82	76.05	58.63

[a]Growing season extends from 15 April through 30 November.

well drained zones. Together, these two species composed 96% of the total basal area at GSW, 90% at LL1, and 72% at LL2.

In this layer, weighted averages calculated by soil drainage class ranged from 2.94 to 4.89 over the three sites, using basal area as the importance measure, and from 2.92 to 4.33 using density (Table 8). These relatively high scores reflect the predominance of red maple (FAC) and white oak (FACU). At every site, weighted averages calculated from basal area figures were significantly higher than those calculated from density figures (Tables 8,9). Index averages ranged from 2.67 to 4.50 (Table 8). At the Laurel Lane sites, there were no significant differences between index averages and weighted averages calculated from either importance measure; at GSW, basal area weighted averages were significantly higher than index averages (Tables 8,10). Although an upward trend in scores from the lower end to the upper end of each transect was discernible in the tree layer, only samples from the wettest drainage class (VPD) on two of the nine transects scored below 3.00 in all of the averaging methods. Wentworth and Johnson's (1986) proposed 3.0 wetland/upland breakpoint clearly was too low for the tree layer at these sites.

Table 7. Distribution of plant species by FWS indicator status (Reed 1987) and life form layer at each site.

Site	Layer	OBL	FACW	FAC	FACU	UPL	Total
GSW	Tree	-	1	3	2	-	6
	Tall shrub	2	8	4	2	-	16
	Low shrub	-	10	7	3	-	20
	Herb	13	23	10	13	2	61
LL1	Tree	1	-	2	1	1	5
	Tall shrub	-	5	4	2	1	12
	Low shrub	-	7	5	4	1	17
	Herb	11	16	13	6	7	53
LL2	Tree	-	-	3	3	1	7
	Tall shrub	-	6	4	2	-	12
	Low shrub	-	9	4	5	-	18
	Herb	4	14	10	18	3	49

Station Analyses

Shrub layers. Sweet pepperbush (Clethra alnifolia) was the dominant shrub throughout each study site in frequency, stem density, and percent cover. This species was present in the low shrub layer at 17 of the 18 stations at GSW, for example. Overall relative stem densities for sweet pepperbush at GSW were 23.7% in the tall shrub layer and 65.5% in the low shrub layer. At LL1, relative densities were 38.2% and 70.6% in the two layers, respectively, and at LL2 the values were 75.2% and 84.5%.

Weighted averages and index averages for the tall shrub layer were low, spanned a very narrow range, and showed no consistent trend from wetland to upland (Tables 11-13). Relative density scores ranged from 2.00 to 3.13 at the three sites, and while 100% of the hydric stations had scores in the "wetland" range (i.e., ≤ 3.00), only one of the 15 nonhydric stations had a score exceeding 3.00.

For tall shrubs, weighted averages based on density did not differ significantly from those based on percent cover at any of the sites (Table 9). Differences between index averages and weighted averages calculated from either importance measure were significant at LL2, but not at the other two sites (Table 10). Due to the absence of a well defined gradient in this layer, there were no significant differences between the scores of hydric and nonhydric stations, using either weighted or index averaging (Table 14), except at LL2. At this site, however, a reverse gradient in density-based

Table 8. Weighted averages and index averages for the tree layer by soil drainage class.

Site	Transect	Soil drainage class	Weighted average Basal area	Weighted average Density	Index average
GSW	1	MWD	3.85	3.50	3.33
		SPD	3.95	3.50	3.50
		PD#	3.78	3.62	3.67
		VPD#	3.00	3.00	3.00
	2	MWD	3.88	3.20	3.50
		PD#	3.59	3.31	3.33
		VPD#	3.00	3.00	3.00
	3	MWD	3.96	3.60	3.50
		PD#	3.93	3.53	3.33
		VPD#	2.94	2.96	2.67
LL1	1	MWD	4.00	4.00	4.00
		SPD	4.51	4.14	4.00
		PD#	3.62	3.67	3.50
		VPD#	3.03	3.03	3.33
	2	MWD	4.64	4.25	4.50
		SPD	3.37	3.38	3.50
		PD#	3.00	3.00	3.00
		VPD#	3.15	2.92	2.67
	3	MWD	4.00	4.00	4.00
		SPD	4.15	3.82	4.00
		PD#	3.72	3.50	3.50
		VPD#	3.19	3.15	3.33
LL2	1	MWD	4.08	4.00	4.00
		SPD#	4.89	4.33	4.00
		PD#	3.00	3.00	3.00
		VPD#	3.30	3.06	3.50
	2	MWD	3.00	3.00	3.00
		SPD	3.00	3.00	3.00
		PD#	nd[a]	nd[a]	nd[a]
		VPD#	3.14	3.14	3.40
	3	MWD	4.30	4.22	4.33
		SPD	4.47	4.00	4.00
		PD#	3.52	3.40	3.80
		VPD#	3.00	3.00	3.00

#Hydric soil; soils not so designated are nonhydric.
[a]No data; no trees found in this plot.

Table 9. Results of paired-sample t-tests comparing weighted averages calculated from different importance measures in the three upper life form layers at each site. Values listed are probabilities that the two sets of scores in each test are the same.

Life form layer	Importance measures	GSW	LL1	LL2
Tree	Basal area/density	0.0052*	0.0231*	0.0416*
Tall shrub	Density/% cover	0.5116	0.8781	0.9298
Low shrub	Density/% cover	0.0018*	0.0007*	0.0696

*Significant difference ($p<0.05$).

Table 10. Results of paired-sample t-tests comparing weighted averages with index averages for each life form layer and importance measure at each site. Values listed are probabilities that the two sets of scores in each test are the same.

Life form layer	Importance measure	GSW	LL1	LL2
Tree	Basal area	0.0014*	0.2373	0.5734
	Density	0.4756	0.4405	0.2521
Tall shrub	Density	0.7178	0.3692	0.0235*
	Percent cover	0.9259	0.9139	0.0155*
Low shrub	Density	0.0094*	0.0001*	0.0014*
	Percent cover	0.0617	0.0006*	0.0006*
Herb	Percent cover	0.0001*	0.0164*	0.0001*
Shrub and herb combined	Combined[a]	0.5744	0.2149	0.9875

*Significant difference ($p<0.05$).
[a]Importance measures are density for the shrub layers and percent cover for the herb layer.

Table 11. Weighted averages (WA) and index averages (IA) for the shrub layers at Great Swamp.

		Tall shrub			Low shrub		
		WA			WA		
Transect	Station	Density	% cover	IA	Density	% cover	IA
1	6	2.00	2.85	2.00	2.24	2.27	2.70
	5	2.27	2.50	2.25	2.61	2.63	2.50
	4#	2.71	2.45	2.60	2.81	2.82	2.75
	3#	3.00	2.03	3.00	2.78	2.59	2.40
	2#	2.00	2.01	2.00	2.71	2.47	2.25
	1#	2.33	2.03	2.33	2.91	2.76	2.17
2	6	2.23	2.63	2.40	2.18	2.19	2.60
	5#	2.76	2.48	2.40	2.96	2.97	2.25
	4#	2.94	2.75	2.80	2.97	3.00	3.00
	3#	2.25	2.34	2.33	2.47	2.27	2.17
	2#	2.75	2.83	2.50	2.83	2.80	2.40
	1#	2.12	2.38	2.40	2.41	2.39	2.20
3	6	2.33	2.53	2.67	2.69	2.61	2.71
	5#	2.73	2.85	2.33	2.75	2.69	2.17
	4#	2.20	2.57	2.50	2.84	2.72	2.80
	3#	2.40	2.29	2.50	2.82	2.74	2.33
	2#	2.14	2.77	2.50	2.52	2.38	2.29
	1#	2.00	2.00	2.00	2.61	2.48	2.25

#Hydric soil station; stations not so designated are nonhydric.

weighted averages was encountered; the nonhydric stations scored lower than the hydric stations. The poor discriminatory power of the tall shrub layer resulted from the compound effects of low species richness, a dearth of OBL and UPL species, and dominance of the study sites by one FAC species, sweet pepperbush.

In the low shrub layer, except for one station that scored 3.86, density-based weighted averages ranged from 2.18 to 3.36 over all sites; most values clustered around 3.00 (Tables 11-13). Once again, there were no consistent trends associated with the moisture gradient. At GSW, all stations scored below 3.00. Although sweet pepperbush was the clear dominant at that site, two FACW species, swamp azalea (Rhododendron viscosum) and inkberry (Ilex glabra), were second and third in abundance and were especially prevalent toward the upslope end of the transects, lowering averages there. At LL1, low shrubs at all of the moderately well drained (nonhydric) stations had density-based weighted averages exceeding 3.00. The

Table 12. Weighted averages (WA) and index averages (IA) for the shrub layers at Laurel Lane 1.

		Tall shrub			Low shrub		
		WA			WA		
Transect	Station	Density	% cover	IA	Density	% cover	IA
1	6	2.00	2.00	2.00	3.86	3.84	3.50
	5	3.00	2.82	3.00	2.99	2.99	3.00
	4#	3.00	3.00	3.00	2.82	2.73	2.50
	3#	2.43	2.60	2.50	2.80	2.67	2.80
	2#	2.60	2.47	2.67	2.90	2.78	2.50
	1#	3.00	3.00	3.00	2.99	2.99	2.50
2	6	3.00	3.00	3.00	3.21	2.92	2.71
	5	3.13	4.12	3.00	2.98	2.96	2.80
	4#	2.36	2.18	2.50	2.74	2.57	2.20
	3#	2.83	2.98	2.75	2.89	2.92	2.60
	2#	3.00	3.00	3.00	3.00	2.96	3.00
	1#	3.00	3.00	3.00	3.00	3.00	3.00
3	6	nd[a]	3.00	nd[a]	3.36	3.02	3.13
	5	3.00	3.00	3.00	2.98	2.84	2.86
	4#	3.00	2.19	3.00	2.91	2.54	2.57
	3#	2.50	2.05	2.67	2.90	2.87	2.50
	2#	2.57	2.62	2.60	2.88	2.61	2.50
	1#	2.50	2.67	2.50	2.91	2.74	2.33

#Hydric soil station; stations not so designated are nonhydric.
[a]No data; no tall shrubs rooted within sample plot.

somewhat poorly drained soils, also classified nonhydric, had scores just below 3.00. The remainder of the stations at that site had hydric soils; weighted averages for those stations ranged from 2.80 to 3.00, again reflecting the abundance of FAC species throughout the length of the transects. At LL2, only two of five nonhydric stations had density-based weighted averages over 3.00 in the low shrub layer. Swamp azalea was common at these stations and largely accounted for the low values.

At LL2, weighted averages calculated from the percent cover of low shrubs did not differ from those based on relative stem density (Table 9). At GSW and LL1, however, percent cover scores were lower than density-based scores. Index averages were significantly lower than density-based weighted averages at all sites, and lower than weighted averages calculated from percent cover data at LL1 and LL2 (Tables 10-13). Differences between weighted averages from hydric and nonhydric stations were inconclusive for

Table 13. Weighted averages (WA) and index averages (IA) for the shrub layers at Laurel Lane 2.

		Tall shrub			Low shrub		
		WA			WA		
Transect	Station	Density	% cover	IA	Density	% cover	IA
1	6	3.00	2.95	3.00	2.98	2.94	2.50
	5#	2.63	2.82	2.33	2.94	2.75	2.25
	4#	3.00	2.86	3.00	2.90	3.00	2.75
	3#	2.93	2.78	2.50	2.97	2.96	2.75
	2#	2.92	2.88	2.50	2.98	2.97	2.67
	1#	2.94	2.75	2.75	2.96	2.87	2.50
2	6	2.40	2.73	2.50	3.21	3.20	2.83
	5	2.85	2.79	2.33	2.97	2.94	2.75
	4#	3.00	3.73	3.00	2.97	2.91	2.50
	3#	3.00	3.00	3.00	3.01	3.03	3.00
	2#	3.00	3.00	3.00	3.06	3.20	3.20
	1#	2.57	2.26	2.67	2.98	2.82	2.50
3	6	2.50	2.81	2.50	3.31	3.11	2.86
	5	2.73	2.57	2.60	2.60	2.56	2.57
	4#	3.00	3.00	3.00	2.86	2.77	2.50
	3#	3.00	3.00	3.00	3.01	3.07	3.33
	2#	3.00	2.67	3.00	3.01	3.01	3.00
	1#	2.71	2.49	2.50	3.00	2.83	3.00

#Hydric soil station; stations not so designated are nonhydric.

the low shrub layer: significant differences occurred at LL1, but not at LL2; at GSW, density-based weighted averages were lower at nonhydric stations than at hydric stations (Table 14). Using index averaging, only LL1 showed significant differences between the hydric and nonhydric stations.

<u>Herb layer</u>. Moisture-related trends in scores were most evident in the herb layer, where weighted and index averages had the widest spread. Ranges of weighted averages were similar over the three sites: at GSW, scores ranged from 1.53 to 3.32; at LL2, from 1.66 to 3.44; and at LL1, from 1.77 to 3.46 (excluding one outlying value, 4.34) (Tables 15-17). GSW again emerged as the wettest site, with only two of the four nonhydric stations having weighted averages over 3.00. At LL1, five of the six nonhydric stations had weighted averages over 3.00 and the sixth equalled 3.00. At LL2, only the moderately well drained stations had weighted averages over 3.00; the other two nonhydric stations (SPD) had scores of 2.82 and 2.90. All of the hydric

Table 14. Results of t-tests comparing hydric and nonhydric soil stations, using weighted averaging (WA) and index averaging (IA). Values listed are probabilities that the scores from hydric and nonhydric stations are the same.

Life form layer	Method	Importance measure	GSW	LL1	LL2
Tall shrub	WA	Density	0.2025	0.6059	0.0479*[a]
		Percent cover	0.2142	0.1726	0.5655
	IA	Density	0.4636	0.8298	0.1514
Low shrub	WA	Density	0.0121*[a]	0.0047*	0.5925
		Percent cover	0.0966	0.0215*	0.8944
	IA	Density	0.1010	0.0050*	0.6841
Herb	WA	Percent cover	0.0062*	0.0022*	0.0007*
	IA		0.0092*	0.0013*	0.0064*
Herbaceous species	WA	Percent cover	0.0001*	0.0075*	0.0004*
	IA		0.0065*	0.0100*	0.0023*
Shrub and herb combined	WA	Combined[b]	0.5736	0.0001*	0.0151*
	IA		0.0650	0.0004*	0.4134

*Significant difference ($p<0.05$).
[a]Trend in scores reverse of normal; mean scores of hydric stations higher than mean scores of nonhydric stations.
[b]Importance measures are density for shrub layers and percent cover for herb layer.

stations, with the exception of one station at LL1, had weighted averages below 3.00.

When compared with weighted averages, index averages showed poorer agreement with hydric soil status on three transects, improved agreement on one transect, and comparable agreement on five transects. In this layer, index averages were significantly higher than weighted averages at all sites (Tables 10, 15-17). Herb layer scores for hydric and nonhydric stations were

Table 15. Weighted averages (WA) and index averages (IA) for the herb layer, herbaceous species, and combined shrub and herb layers at Great Swamp.

Transect	Station	Herb layer WA	Herb layer IA	Herbaceous species WA	Herbaceous species IA	Combined layers[a] WA	Combined layers[a] IA
1	6	3.32	3.40	4.00	3.86	2.52	2.70
	5	2.47	2.94	2.30	3.17	2.45	2.56
	4#	2.67	2.85	2.57	3.00	2.73	2.73
	3#	2.58	2.75	2.50	2.71	2.78	2.72
	2#	1.77	2.09	1.50	1.67	2.16	2.11
	1#	1.58	2.04	1.32	1.69	2.27	2.18
2	6	2.92	3.30	3.78	3.83	2.44	2.77
	5#	2.63	2.85	2.06	3.00	2.78	2.50
	4#	2.66	3.18	2.41	3.40	2.86	2.99
	3#	1.94	2.67	1.65	2.75	2.22	2.39
	2#	1.53	1.88	1.29	1.56	2.37	2.26
	1#	1.92	2.15	1.40	1.69	2.15	2.25
3	6	3.11	3.12	3.89	3.60	2.71	2.83
	5#	2.77	2.79	2.07	3.33	2.75	2.43
	4#	2.60	3.10	2.24	3.20	2.55	2.80
	3#	1.85	1.91	1.40	1.36	2.36	2.25
	2#	1.74	1.80	1.25	1.40	2.13	2.20
	1#	1.74	2.12	1.41	1.57	2.12	2.12

#Hydric soil station; stations not so designated are nonhydric.
[a]Importance measures are density for the shrub layers and percent cover for the herb layer.

significantly different at all sites using both weighted and index averaging (Table 14).

The wider range of weighted averages in the herb layer suggested that herbaceous species might better reflect soil moisture changes than woody species. To test this, we separated the herbaceous species from the woody species in this layer and calculated weighted and index averages for the herbaceous species alone (Tables 15-17). Weighted averages for the herbaceous species had a wider range than the herb layer averages (1.06-4.40 over all sites), but the number of nonhydric stations scoring less than or equal to 3.00 (5 of 15), and the number of hydric stations with weighted averages over 3.00 (1 of 39) remained unchanged. Index averages for the herbaceous species were generally higher than the herb layer index averages;

Table 16. Weighted averages (WA) and index averages (IA) for the herb layer, herbaceous species, and combined shrub and herb layers at Laurel Lane 1.

Transect	Station	Herb layer		Herbaceous species		Combined layers[a]	
		WA	IA	WA	IA	WA	IA
1	6	4.34	3.73	3.52	3.67	3.40	3.08
	5	3.01	3.24	2.80	3.50	3.00	3.08
	4#	2.89	3.29	2.85	3.57	2.90	2.93
	3#	3.05	3.06	3.13	3.57	2.76	2.79
	2#	2.53	2.93	2.47	3.14	2.68	2.70
	1#	1.96	2.08	1.22	1.60	2.65	2.53
2	6	3.46	3.42	4.40	4.25	3.22	3.04
	5	3.02	3.39	2.96	3.57	3.04	3.06
	4#	2.90	2.94	2.94	3.50	2.67	2.55
	3#	2.88	2.93	2.90	3.14	2.87	2.76
	2#	2.23	2.64	1.87	2.70	2.74	2.88
	1#	1.77	2.07	1.06	1.67	2.59	2.69
3	6	3.35	3.53	3.68	4.00	3.36	3.33
	5	3.00	3.31	2.96	3.43	2.99	3.06
	4#	2.95	2.93	2.97	3.00	2.95	2.83
	3#	2.53	2.92	2.47	3.00	2.64	2.70
	2#	2.42	2.67	2.39	2.82	2.62	2.59
	1#	1.89	1.92	1.10	1.43	2.43	2.25

#Hydric soil station; stations not so designated are nonhydric.
[a]Importance measures are density for the shrub layers and percent cover for the herb layer.

all of the nonhydric stations had scores greater than 3.00, but 10 of the hydric stations also had scores exceeding 3.00. At every site, both weighted and index averages for the herbaceous species differed significantly between hydric and nonhydric stations (Table 14). In summary, weighted averaging results were similar whether herbaceous species alone or all herb layer species were included in the analysis; however, the agreement between index averages and hydric soil status was better when all herb layer species were included.

Combined shrub and herb layers. Correlations between hydric soil status and vegetation averages were generally poorer when shrub and herb layer data were combined than when herb layer data alone were used (Tables 15-17). When results from the herb, low shrub, and tall shrub layers were averaged, all of

Table 17. Weighted averages (WA) and index averages (IA) for the herb layer, herbaceous species, and combined shrub and herb layers at Laurel Lane 2.

Transect	Station	Herb layer WA	Herb layer IA	Herbaceous species WA	Herbaceous species IA	Combined layers[a] WA	Combined layers[a] IA
1	6	3.44	3.50	3.77	3.86	3.14	3.00
	5#	2.79	3.38	2.70	3.57	2.79	2.65
	4#	2.57	2.93	2.49	3.38	2.82	2.89
	3#	2.23	2.38	2.16	2.29	2.71	2.54
	2#	1.86	2.54	1.79	2.29	2.59	2.57
	1#	1.66	2.27	1.51	2.17	2.52	2.51
2	6	3.17	3.29	3.09	3.83	2.92	2.87
	5	2.82	3.00	2.73	3.33	2.88	2.69
	4#	2.75	3.00	2.68	3.40	2.91	2.83
	3#	2.84	2.92	2.81	3.14	2.95	2.97
	2#	2.29	2.69	2.26	2.70	2.78	2.96
	1#	1.74	2.56	1.49	2.13	2.43	2.58
3	6	3.34	3.56	3.09	3.80	3.05	2.97
	5	2.90	2.94	3.36	3.60	2.74	2.70
	4#	2.69	2.77	2.54	3.00	2.85	2.76
	3#	2.33	3.13	2.21	3.00	2.78	3.15
	2#	2.18	2.67	2.08	2.56	2.73	2.89
	1#	2.03	2.40	1.79	1.80	2.58	2.63

#Hydric soil station; stations not so designated are nonhydric.
[a]Importance measures are density for the shrub layers and percent cover for the herb layer.

the weighted averages at the hydric stations were below 3.00. However, the agreement between the nonhydric soils and the combined layer weighted averages was poorer than with the herb layer alone. Nine of the 15 nonhydric stations had combined layer weighted averages of 3.00 or less, compared to only 5 using just the herb layer scores. At LL1, combined layer index averages were in perfect agreement with hydric soil status at all stations, but at GSW and LL2, all stations scored below 3.00.

Weighted and index averages for the combined layers were not significantly different at any site (Table 10). This was because weighted averages were higher than index averages in the shrub layers, but lower than index averages in the herb layer. Differences in scores between hydric and nonhydric stations were inconclusive (Table 14). Using weighted averaging,

significant differences were observed at LL1 and LL2; using index averaging, a significant difference was found only at LL1.

Appendix B presents an outline of weighted and index averaging results by soil series.

Belt Transect Analyses

Shrub layer. Weighted and index averaging of data from shrub layer belt quadrats produced the same narrow ranges of values observed in the station results described above. A trend in scores reflecting the moisture gradient was apparent on several transects, but at least one transect at each site showed no trend, with all scores falling at or slightly below 3.00. Once again, this was due to the predominance of FAC and FACW shrub species throughout the study sites. Because of the difficulties in interpretation, no further analysis was performed on the shrub belt transect data.

Herb layer. Herb layer belt data produced weighted and index averages that increased in a consistent fashion from the lower end to the upper end of each transect (Figures 3 and 4). Comparison of Figures 3 and 4 with Figure 2 reveals that vegetation scores mirror elevational changes along the transects. As observed in the station results, weighted averages from the belt quadrats were significantly lower than index averages when analyzed by site in paired-sample t-tests.

The small size (0.5 x 1 m) and contiguous placement of the belt quadrats, coupled with irregular microtopography, produced considerable variability in weighted and index averages over short segments of each transect (Figures 3 and 4). Consequently, identification of a clear wetland/upland boundary line was impractical in every instance. We decided, instead, to identify and delimit a "boundary zone" within which a boundary line might be expected to lie.

To ensure objectivity in boundary zone identification, we combined belt quadrats into 5-m intervals (10 quadrats per interval) and devised a rule to classify the intervals as wetland, upland, or transitional, relative to the 3.00 breakpoint. A quadrat was considered wetland if its score was below 3.00, upland if above 3.00, and inconclusive if equal to 3.00. Interval classification commenced at the upslope end of the transect. If the first 10 quadrats at the upslope end of the transect were all upland quadrats, classification of 5-m intervals did not begin until the first non-upland quadrat was encountered. An interval was classified upland if at least 7 of the 10 quadrats had scores greater than 3.00; likewise, an interval was classified wetland if at least 7 of the 10 quadrats had scores less than 3.00. If neither case held (i.e., the interval was not clearly upland or wetland), it was classified transitional. Interval classification continued down the transect in this manner until at least three consecutive intervals were classified wetland.

In the likely event that intervals alternated in classification, they were combined into blocks of three and subjected to a majority rule, beginning with the first non-upland interval adjacent to the upslope end of

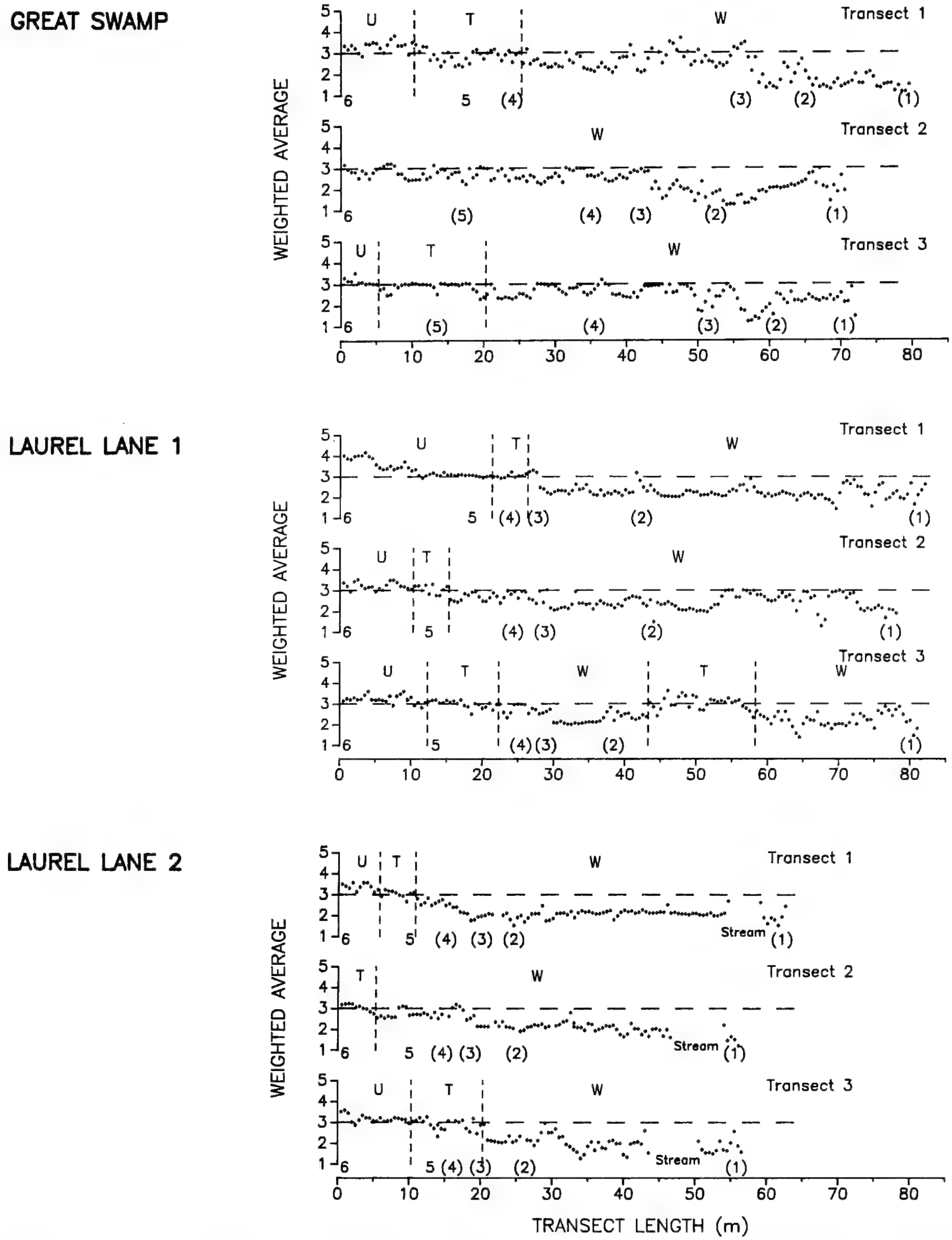

Figure 3. Profiles of weighted averages for herb belt quadrats, showing upland (U), wetland (W), and transitional (T) zones derived from the scores. Stations are numbered 1-6; those in parentheses have hydric soils.

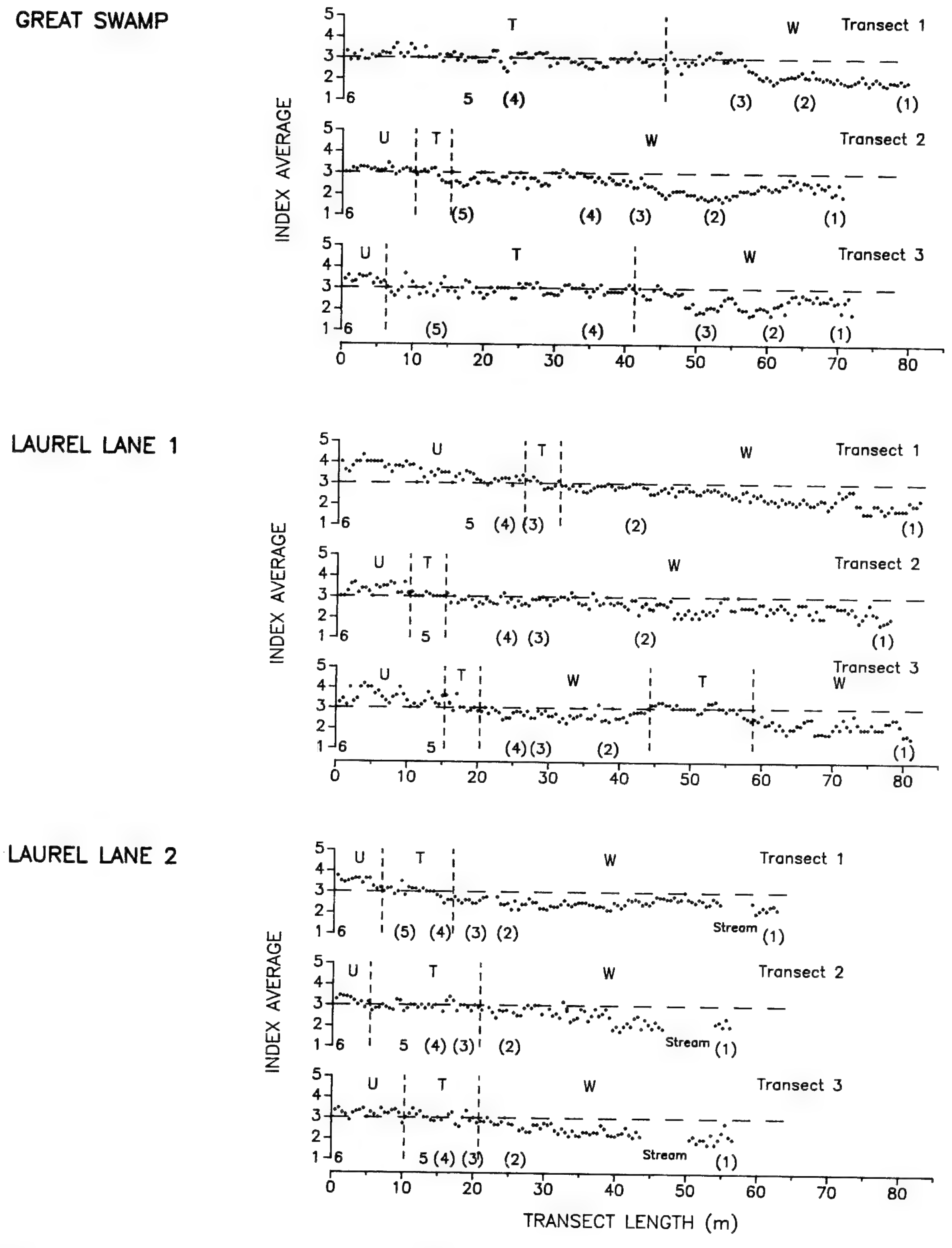

Figure 4. Profiles of index averages for herb belt quadrats, showing upland (U), wetland (W), and transitional (T) zones derived from the scores. Stations are numbered 1-6; those in parentheses have hydric soils.

the transect. Blocks were classified according to the dominant interval classification; for example, if 2 of 3 intervals in a block were classified wetland, the whole block was classified wetland. If a block was composed of wetland, transitional, and upland intervals, the entire block was classified transitional.

Through this procedure, upland, wetland, and transitional zones were identified on the majority of transects (Figures 3 and 4). In one case (Transect 2, GSW, weighted averages), neither transitional nor upland zones were identified; the entire transect was classified wetland. Two transitional zones were identified on Transect 3 at LL1, using either weighted or index averages.

The boundary zone was considered to be the transitional zone lying between wetland and upland zones. Using weighted averages, boundary zones varied in width from 5 to 15 m; boundary zones based on index averages ranged in extent from 5 to 46.5 m. In those instances where the boundary zone extended to the upslope end of the transect (Transect 2, LL2, weighted averages; Transect 1, GSW, index averages), the width of the boundary zone must be considered conservative since the zone may have continued beyond the end of the transect.

In most cases, the locations of boundary zones identified from weighted averaging of belt quadrat data correlated well with the hydric soil status of stations located within those zones (Figure 3). On seven of the eight transects with boundary zones, this zone included at least one "border" station (i.e., the wettest nonhydric station or the driest hydric station on the transect). Similarly, there was a strong correlation between boundary zone location and weighted averages calculated from station data.

Because index averages generally were higher than weighted averages for the same belt quadrats, index average boundary zones tended to be lower on the slopes than weighted average boundary zones. Thus, on six of the nine transects, index averaging resulted in narrower wetland zones. Using weighted averages, Transect 2 at GSW was classified entirely wetland; index averages were high enough to produce both upland and boundary zones on this line. There was a strong correlation between the location of index average boundary zones and index averages calculated from station data. Soil border stations fell within index average boundary zones on six of the nine transects.

DISCUSSION

IDENTIFICATION OF MOISTURE GRADIENTS

To effectively partition an ecotone or transition zone using any environmental or biotic variable, a well defined gradient must be apparent for that variable. On all nine transects at our study sites, moisture gradients were clearly defined by topographic profiles and water table data gathered over three growing seasons. Water levels were close to the ground surface at the lower end of each transect and were progressively farther below the surface as the transect extended up slope.

Soil profile descriptions at systematically located stations along each transect also clearly demonstrated a moisture gradient. Soil drainage classes ranged from moderately well drained at the upper end of each transect to very poorly drained at the lower end. The hydric status of the soil series also reflected the moisture gradient; series were classified nonhydric toward the upper end of the transects and hydric toward the lower end.

The correlation between mean water levels and hydric soil status was only approximate. Mean growing season water levels for the hydric/nonhydric border stations ranged between -42 and -105 cm at GSW, between -61 and -96 cm at LL1, and between -67 and -151 cm at LL2. These values are wide-ranging simply because the border stations were not located precisely on a wetland boundary line, but at variable--and unknown--distances from it. The mean water level at any boundary line drawn between adjacent border stations can be expected to lie within the above ranges. It must be emphasized, however, that these data represent only a short-term hydrologic record. Because long-term data are seldom available for specific sites, absolute hydrologic values generally should not be used for wetland boundary determination.

Weighted and index averaging of vegetation sampled in four life form layers along each transect indicated that well defined gradients were apparent only in certain layers. The gradient was most pronounced in the herb layer; the ranges of both weighted and index averages were widest in this layer, and the pattern of scores in the herb belt quadrats closely mirrored the elevational gradient. The tree layer also demonstrated a gradient in weighted and index averages, but the range of scores was fairly narrow, and trends in scores were not consistent on all transects. In the tall and low shrub layers, the predominance of facultative species (FACW, FAC, FACU)--sweet pepperbush (FAC) in particular--along the entire length of most transects obscured gradients in vegetation scores. The ranges of scores were very narrow for both layers.

When attempting wetland boundary delineation using vegetation, several authors (e.g., Roman et al. 1985; Wentworth and Johnson 1986; Adams et al. 1987) have combined data from all life form layers, assuming that the entire community best represents the vegetation response to soil moisture conditions. However, numerous examples in the ecological literature demonstrate that different layers within a plant community respond differently to environmental gradients (Cantlon 1953; Rogers 1980; Ehrenfeld and Gulick 1981; McCune and Antos 1981). At our study sites, the herb layer demonstrated the strongest gradient in scores, and the shrub layers, the weakest. As would be expected from these results, combining shrub and herb layer data reduced our ability to discern the gradient. The herb layer provided the greatest opportunity for distinguishing wetland from upland.

Researchers using weighted and index averaging in other wetland types in several geographic regions have found that other layers best distinguished the moisture gradient within transition zones. Carter et al. (1988) described the tree layer as having the most consistent wetland/upland trends at the Great Dismal Swamp in Virginia and North Carolina. Data collected by Dick-Peddie et al. (1987) in New Mexico forested riparian wetlands indicated that the tree and shrub layers were better correlated with the hydric status of soils than was the herb layer.

SOIL-VEGETATION CORRELATIONS

At our study sites, the extent of agreement between vegetation scores and hydric soil status generally depended on the clarity of the vegetation gradient and the range of scores. The frequency of agreement in station classification (wetland/upland) between hydric soil status and both weighted and index averaging results, using a 3.00 breakpoint, varied with life form layer. Agreement was best for the herb layer; classifications based on herb layer weighted averages agreed with soil classifications at nearly 90% of the 54 stations, while herb layer index averages agreed with soil classification at 83% of the stations. Agreement was poorer for the shrub layers (72%-75% of all stations), largely because of the lack of consistent trends in shrub scores along the transects. Agreement between soils and vegetation varied considerably among sites; generally, it was best at LL1 and poorest at LL2.

Only in the herb layer did significant differences between the scores of hydric and nonhydric stations occur consistently. The differences between hydric and nonhydric stations for tall shrub, low shrub, and combined layers were inconclusive for either averaging method; in every case, differences occurred at some sites and not at others.

These statistical comparisons between hydric and nonhydric stations are somewhat artificial because only part of the possible range of hydric and nonhydric conditions was sampled. Our analyses did not include vegetation scores from well drained or excessively drained soils, or from the wettest wetland forests in southern Rhode Island. Lowry (1984), for example, described red maple swamps with much longer hydroperiods than we observed at our wettest stations. In addition, sampling only in the immediate vicinity of the wetland boundary reduces the likelihood of significant differences

between hydric and nonhydric stations, especially where FAC species predominate.

EVALUATION OF THE 3.0 VEGETATION BREAKPOINT

Comparison of the soils and vegetation breakpoints was possible only for the herb and tree layers, where the vegetation gradient was clear and relatively consistent. Agreement was reasonably good in the herb layer. The location of the weighted averaging breakpoint for herbs coincided with the hydric/nonhydric soils break on three of the nine transects, one at each site. On the other transects, either the vegetation breakpoint was one station higher than the soils break (4 transects) or there was no clear vegetation break (2 transects). The index averaging breakpoint for herbs coincided with the hydric soils break on only two transects, both at LL1. On two transects, the index averaging breakpoint was lower than the hydric soils break, and on two other transects, it was higher; in three cases, no clear vegetation breakpoint was evident. All of these results suggest that the relationship between weighted averages and soil status was stronger and more consistent than the relationship between index averages and soil status.

In the tree layer, the 3.0 breakpoint, using either weighted or index averaging, was clearly too low relative to the soils break. The predominance of FAC and FACU trees raised most scores above 3.0 throughout the transects; weighted and index averages in the vicinity of the hydric/nonhydric soils break ranged from about 3.5 to 4.0.

COMPARISON OF WEIGHTED AND INDEX AVERAGING

The relationship between weighted and index averages varied with life form layer, importance measure, and site. In the tree layer, differences were not significant, except at GSW, where basal area weighted averages were higher than index averages. In both shrub layers, differences were not consistent across sites; when differences occurred, weighted averages were always higher than index averages. In contrast, herb layer weighted averages were significantly lower than index averages at all sites. Due to the conflicting results found in the shrub and herb layers, there were no differences between weighted and index averages when data from these layers were combined. Recent studies (e.g., Wentworth and Johnson 1986; Dick-Peddie et al. 1987) have reported close agreement between weighted averages and index averages. Our results suggest that nonsignificant differences in combined layer analyses may mask significant differences within individual layers.

Variation in the relationship between weighted and index averages results from two factors: (1) the relative importance of plants in the various FWS indicator categories, and (2) species richness in the various indicator categories. For example, if a layer has a relatively large number of species in the wetter categories (OBL, FACW) but great importance (percent cover, density, basal area) in the drier categories (FACU, UPL), index averages will tend to be lower than weighted averages for that layer. Since

species richness was comparable among the indicator categories at our sites--and the principal categories were facultative (FACW, FAC, FACU)--weighted averages generally were greater than index averages whenever FAC and FACU plants were most important, as in the tree and shrub layers. Where FACW and FAC plants were most important, index averages tended to be higher than weighted averages, as in the herb layer.

Weighted averaging was judged to be the preferred method in our study because there was a stronger correlation between weighted averages and hydric soil status than between index averages and hydric soil status, and because boundary zones generated from weighted averaging of belt quadrat data generally were narrower than those generated from index averaging.

Statistical comparisons of weighted and index averages over an entire site may obscure varying relationships between the methods within that site. The test results presented above simply indicate whether one of the methods produced higher scores than the other at a particular site. In fact, the relative differences in scores may vary among transects and from one end of a transect to the other.

COMPARISON OF IMPORTANCE MEASURES

Although significant differences between importance measures did occur in some layers at some sites, the meaning of these results is difficult to interpret. In our view, the choice of an importance measure should be based on ecological and sampling considerations, such as the capability of the measure to accurately reflect a species' influence on the rest of the layer or community, as well as time constraints, measurement precision, and repeatability of results among investigators.

SOURCES OF ERROR

Given the wide geographic variation in the Northeast Region, the regional indicator status assigned to a particular species may more accurately describe the ecology of that species in some parts of the region than others. Local misclassifications can affect the accuracy of weighted and index averaging results and the strength of soil-vegetation correlations. Inkberry, classified in Region 1 as FACW, occurred in abundance at the upper end of Transects 1 and 2 at GSW, and substantially lowered weighted averages in both the herb and low shrub layers at the MWD stations. In the most dramatic example, at Station 6 on Transect 1 at GSW, inkberry composed 54% of the relative stem density in the low shrub layer; changing the FWS indicator status for this species from FACW to FAC would have raised the density-based weighted average for this station from 2.24 to 2.78. The distribution of inkberry at our sites and elsewhere in southern Rhode Island (authors' personal observations) leads us to believe that this species might be more accurately classified FAC in this locality.

We felt so strongly that swamp azalea should not be classified OBL that we changed the status to FACW for the purposes of this study. Even when

classified FACW, the abundance of this species at the upper end of Transect 2 at LL2 contributed importantly to the relatively low weighted and index averages observed in the low shrub layer there.

While we are confident that soil series were correctly identified at the various stations, we believe that in one case the hydric soil status was incorrect. The Wareham soil series is designated hydric in the national hydric soils list (SCS 1985). At 13 of the 14 stations where Wareham soils occurred in our study, the soil was found to be poorly drained. In those cases a hydric designation appeared to be appropriate. At Station 5 on Transect 1 at LL2, the Wareham soil was somewhat poorly drained. According to hydric soil criteria in the national list, somewhat poorly drained soils should be considered hydric only if the water table lies within 15 cm of the ground surface at some time during the growing season. Because the water level at this station never rose to within even 40 cm of the surface during three consecutive growing seasons, and because the water levels at this station were generally comparable to the other SPD, but nonhydric, stations, we believe the hydric designation to be incorrect. Our contention receives support from Tiner and Veneman (1987) who stated that the Wareham series has both hydric and nonhydric members. Since the hydric designation of soil series in the national list was the "truth" against which weighted and index averaging results were compared, an error in hydric status could have major impact on conclusions about soil-vegetation correlations and breakpoint locations.

Another factor that might affect agreement between hydric soil status and vegetation averages is the local variability in soil properties at a sampling station. In every case, our soil pits were placed within 1 m of the end of a shrub subplot, at roughly the same elevation as the water table well. Nevertheless, local variability in soils must be considered a potential source of error. While vegetation data were collected over a relatively broad area (19 m^2) at each station, the soil description was based on a single sample. Local variation would be especially critical near the hydric/nonhydric breakpoint where small differences in water table elevation could bring about a change in hydric soil status.

To assess local variability among herb quadrat scores, we calculated coefficients of variation (CV) for both weighted and index averages for the eight 0.5x1-m quadrats composing the herb layer sample at each station. For weighted averaging, the mean CV at GSW was 15.9%; at LL1, 10.0%; and at LL2, 9.5%. For index averaging, the mean values were 9.6%, 8.4%, and 6.7% for the three sites, respectively. Using a CV of 10%, an herb quadrat scoring 3.00 would have a standard deviation of 0.30 (i.e., two-thirds of the scores would range from 2.70 to 3.30). Much of the variability among scores of contiguous belt quadrats (Figures 3 and 4) is thus easily explained. Local variability might be reduced through the use of larger quadrats, but quadrat size must be limited, to some extent, by the slope of the moisture gradient and time constraints.

IDENTIFICATION OF WETLAND BOUNDARIES

The belt transect analyses conducted in this study demonstrated that weighted or index averaging methods may be useful in identifying the approximate location of a wetland regulatory boundary, once a standard breakpoint value has been established. In most cases, however, vegetation averaging methods probably will not produce a clear boundary line. Vegetation is distributed as a continuum along the moisture gradient, and even minor changes in surface elevation or soil properties will cause plot averages to oscillate. Such oscillation will be most pronounced where the slope of the moisture gradient is least.

Consequently, wetland managers may be forced to accept a boundary zone rather than a boundary line when using vegetation averaging procedures for wetland edge determinations. Placement of a regulatory line may be aided by inspection of the hydric status of soils within the vegetative boundary zone, but soil properties can be expected to oscillate along the moisture gradient as well. Final boundary placement may have to be somewhat arbitrary in such cases. From a resource management standpoint, inclusion of any zones of uncertain classification within the regulated wetland would be the most appropriate course of action.

CONCLUSIONS

- Wetland boundaries can be delineated using vegetation data only where there is a well defined vegetation gradient that is closely correlated with the soil moisture gradient.

- Within a given plant community, moisture related vegetation gradients may be better defined in some life form layers than others. As a result, certain layers may be more useful than others in the identification and delineation of wetlands. In some cases, single layers may yield more useful information than the entire sum of layers at a site. At our study sites, herb layer vegetation exhibited the most clearly defined gradient, correlated best with the hydric status of soils, and permitted the most precise discrimination between wetland and upland using weighted or index averaging procedures.

- Where entire wetland transition zones are dominated by facultative (FACW, FAC, FACU) species--a common occurrence in deciduous wetland forests of southern New England--moisture related vegetation gradients may be obscured. In these cases, accurate wetland boundary determination using weighted or index averaging procedures may be exceedingly difficult to accomplish.

- Agreement between the proposed 3.0 breakpoint for weighted and index averaging (Wentworth and Johnson 1986) and the breakpoint based on hydric status of soils (SCS 1985) can be expected to vary with site, life form layer, averaging method, and importance measure. In this study, agreement was reasonably good for the herb layer only.

- In our study, the relationship between weighted averages and index averages varied in a complex fashion among life form layers, importance measures, and sites. In any given situation, differences between these two types of averages are a function of the relative importance of the plants in the various FWS indicator categories and species richness in those various categories. Relative differences between weighted and index averages may vary locally within a site.

- In the great majority of cases, the FWS indicator status assigned to species sampled at our sites seemed appropriate. However, misclassification of even one or two important species may have a major adverse impact on wetland identification and delineation using weighted averaging procedures. Even regional classification

of certain species may be too gross to permit accurate wetland determinations at specific sites; subregional classification should be considered for such species.

Efforts to correlate soils, vegetation, and hydrology for the purpose of wetland boundary determination will founder unless firm boundary criteria can be established for one of the parameters at the outset. In this study, the hydric soil designations in the national list were accepted as "truth." The hydric or nonhydric classification of soils at our sites appeared to be correct at every station except one, where a SPD Wareham soil occurred. We believe that those series, such as Wareham, that contain both hydric and nonhydric members, should be clearly identified in the national list. Criteria for distinguishing hydric from nonhydric members in the field also should be provided.

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APPENDIX A

Plant species occurring at the three study sites, along with FWS indicator status (Reed 1987) and distribution by layer. Values in the matrix represent the number of sites at which a species occurred in a particular layer.

Species[a]	Status[b]	Tree	Tall shrub	Low shrub[c]	Herb
Acer rubrum	FAC	3	3	3	3
Alnus serrulata	OBL		1		
Amelanchier sp.	na			3	3
Anemone quinquefolia	FACU				3
Apios americana	FACW			1	1
Aralia nudicaulis	FACU				3
Arisaema triphyllum	FACW				3
Aronia arbutifolia	FACW		2	3	3
Aster acuminatus	UPL				1
Aster novi-belgii	FACW				2
Aster sp.	na				1
Betula lutea	FAC	2			3
Carex howeii	OBL				2
Carex interior	OBL				1
Carex lonchocarpa	OBL				2
Carex pensylvanica	UPL				3
Carex seorsa	FACW				2
Carex sp.	na				3
Carex stricta	OBL				1
Carex vesicaria	OBL				1
Chamaecyparis thyoides	OBL	1			2
Chimaphila maculata	UPL				1
Cinna arundinacea	FACW				1
Clethra alnifolia	FAC		3	3	3
Cornus amomum	FACW			1	1
Cornus sp.	na				1
Crataegus sp.	na			1	
Cuscuta compacta	na				2
Decodon verticillatus	OBL				1
Dryopteris cristata	FACW				1
Fagus grandifolia	FACU	2		1	1
Fraxinus nigra	FACW				1

(Continued)

Appendix A. (Continued)

Species[a]	Status[b]	Tree	Tall shrub	Low shrub[c]	Herb
Fraxinus pennsylvanica	FACW			1	1
Galium sp.	na				1
Gaultheria procumbens	FACU				3
Gaylussacia baccata	FACU			3	3
Glyceria striata	OBL				1
Hamamelis virginiana	FAC				1
Ilex glabra	FACW			2	3
Ilex opaca	FACU				1
Ilex verticillata	FACW		2	3	3
Impatiens capensis	FACW				1
Iris versicolor	OBL				1
Kalmia angustifolia	FAC			1	3
Kalmia latifolia	FACU			1	1
Leucothoe racemosa	FACW			3	2
Lilium superbum	FACW				3
Lindera benzoin	FACW		1	2	3
Lycopodium complanatum	FACU				1
Lycopodium obscurum	FACU				3
Lycopus uniflorus	OBL				1
Lyonia ligustrina	FACW		2	3	3
Lysimachia terrestris	OBL				2
Maianthemum canadense	FAC				3
Medeola virginiana	na				3
Melampyrum lineare	FACU				2
Mitchella repens	FACU				2
Monotropa uniflora	FACU				3
Nyssa sylvatica	FAC	3	1	3	3
Onoclea sensibilis	FACW				1
Osmunda cinnamomea	FACW				3
Osmunda regalis	OBL				2
Parthenocissus quinquefolia	FACU				3
Pinus strobus	FACU	1			3
Polygonum arifolium	OBL				1
Polygonum punctatum	OBL				1
Polygonum sagittatum	OBL				1
Prunus serotina	FACU			3	3
Pteridium aquilinum	FACU				2
Quercus alba	FACU	3		1	3
Quercus coccinea	UPL	2			3
Quercus ilicifolia	UPL			1	
Quercus palustris	FACW	1			1
Rhododendron viscosum	FACW		2	3	3
Rosa palustris	OBL			1	1
Rubus alleghaniensis	FACU			1	1

(Continued)

Appendix A. (Concluded)

Species[a]	Status[b]	Tree	Tall shrub	Low shrub[c]	Herb
Rubus hispidus	FACW				3
Scutellaria lateriflora	FACW				1
Smilax glauca	FACU		2	2	3
Smilax herbacea	FAC			1	
Smilax rotundifolia	FAC		3	3	3
Solanum dulcamara	FAC				1
Solidago rugosa	FAC				1
Solidago uliginosa	OBL				3
Sphagnum spp.	OBL[d]				3
Spiraea latifolia	FAC				1
Symplocarpus foetidus	OBL				3
Thalictrum pubescens	FACW				2
Thelypteris simulata	FACW				3
Thelypteris thelypteroides	FACW				2
Toxicodendron radicans	FAC				3
Toxicodendron vernix	OBL			1	
Trientalis borealis	FAC				3
Uvularia sessilifolia	FACU				3
Vaccinium angustifolium	FACU				3
Vaccinium corymbosum	FACW		3	3	3
Vaccinium vacillans	UPL				3
Viburnum cassinoides	FACW		3	3	3
Viburnum recognitum	FACW		1	3	3
Viola cucullata	FACW				1
Viola pallens	OBL				2
Vitis labrusca	FACU			2	1

[a]Taxonomy of vascular plants is according to the National List of Scientific Plant Names (SCS 1982).
[b]OBL = Obligate Wetland, FACW = Facultative Wetland, FAC = Facultative, FACU = Facultative Upland, UPL = Obligate Upland, na = no status assigned.
[c]All shrub species sampled in belt transects are included in this column.
[d]Indicator status assigned by authors; mosses not listed in Reed (1987).

APPENDIX B

Correlations Between Vegetation Scores and Soil Series

To permit comparisons between our research results and those of other soil-vegetation correlation studies sponsored by the National Ecology Research Center, we calculated weighted and index averages for the shrub and herb layers for each soil series at our sites. Because our study was designed to sample vegetation and soils by drainage classes, results compiled by soil series must be interpreted with caution. Two major limitations are that 1) the number of sampling stations within the various soil series was generally small and highly variable, and 2) the sampling stations did not sample the full range of soil moisture conditions within any of the series.

Some of the same general conclusions that were drawn from analyses by soil drainage class hold for the analysis by soil series. The results were not tested statistically because of small sample sizes, but differences among the vegetation layers were apparent in both weighted averages and index averages (Table B-1). Scores for the tall and low shrub layers exhibited a narrow range and showed no obvious trends from wetland to upland; most scores ranged between 2.5 and 3.0. When shrub layer data from all sites were combined, weighted and index averages were 3.00 or less for both hydric and nonhydric series. The nonhydric Sudbury series (MWD) had the lowest vegetation score in both shrub layers. This series was represented by only one sampling station, at which inkberry and swamp azalea were abundant. The FWS indicator status for these two species in Region 1 is FACW amd OBL, respectively (Reed 1987). As indicated earlier, we changed the status of swamp azalea to FACW prior to our calculations of vegetation averages. If the status of inkberry were changed to FAC--which we feel is more appropriate in our locale--the discrepancy between hydric status and vegetation scores for the Sudbury station would be reduced.

The herb layer weighted and index averages demonstrated more consistent agreement with the hydric status of the series. Scores increased steadily from wetland to upland at individual sites, and when data from all sites were combined (Table B-1). The nonhydric series, Sudbury and Deerfield, had herb layer scores above 3.00, except for the Deerfield series at the Great Swamp. The VPD hydric series (Carlisle, Adrian, and Scarboro), which were clearly located in wetland, had scores well below 3.00 (1.81-2.78). The hydric Wareham and Walpole series, which were predominantly PD (Wareham was represented by one SPD sample as well), had herb-layer scores ranging from 2.67 to 3.03.

When data from all sites were combined, three soil series had a large enough sample size to justify estimation of variability in herb layer scores:

Table B-1. Weighted and index averages for shrub and herb layers by soil series.

Site	Soil series	Soil drainage class[a]	n	Weighted average[b] Tall shrub	Weighted average[b] Low shrub	Weighted average[b] Herb	Index average[b] Tall shrub	Index average[b] Low shrub	Index average[b] Herb
GSW	Sudbury	MWD	1	2.00	2.24	3.32	2.00	2.70	3.40
	Deerfield	MWD/SPD	3	2.28	2.49	2.83	2.44	2.60	3.12
	#Wareham	PD	5	2.67	2.87	2.67	2.53	2.59	2.95
	#Scarboro	VPD	9	2.33	2.67	1.85	2.40	2.27	2.16
LL1	Deerfield	MWD/SPD	6	2.83[c]	3.23	3.36	2.80[c]	3.00	3.44
	#Wareham	PD	5	2.62	2.83	2.85	2.68	2.52	3.03
	#Walpole	PD	1	3.00	2.91	2.95	3.00	2.57	2.93
	#Scarboro	VPD	5	2.73	2.78	2.16	2.75	2.67	2.45
	#Adrian	VPD	1	3.00	2.99	1.96	3.00	2.50	2.08
LL2	Deerfield	MWD/SPD	5	2.69	3.01	3.13	2.59	2.70	3.26
	#Wareham	SPD/PD	4	2.91	2.92	2.70	2.83	2.50	3.02
	#Scarboro	VPD	4	2.98	3.01	2.42	2.87	3.07	2.78
	#Adrian	VPD	2	2.96	2.99	2.02	2.75	2.83	2.60
	#Carlisle	VPD	3	2.74	2.98	1.81	2.64	2.67	2.41
All sites	Sudbury	MWD	1	2.00	2.24	3.32	2.00	2.70	3.40
	Deerfield	MWD/SPD	14	2.66[d]	2.99	3.17	2.65[d]	2.81	3.31
	#Wareham	SPD/PD	14	2.72	2.87	2.74	2.67	2.54	3.00
	#Walpole	PD	1	3.00	2.91	2.95	3.00	2.57	2.93
	#Scarboro	VPD	18	2.59	2.78	2.06	2.60	2.56	2.38
	#Adrian	VPD	3	2.97	2.99	2.00	2.83	2.72	2.43
	#Carlisle	VPD	3	2.74	2.98	1.81	2.64	2.67	2.41

[a]Determined by soil morphology; MWD = moderately well drained, SPD = somewhat poorly drained, PD = poorly drained, VPD = very poorly drained.
[b]Based on stem density for shrubs and percent cover for herbs.
[c]n=5
[d]n=13
#Hydric series; series not so designated are nonhydric.

Deerfield (14 stations), Wareham (14 stations), and Scarboro (18 stations). Coefficients of variation calculated for weighted averages were 13.6%, 5.5%, and 18.4% for these series, respectively. For index averages, the respective coefficients of variation were 7.2%, 6.0%, and 17.7%.

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15. Supplementary Notes

16. Abstract (Limit: 200 words)

The extent of agreement between the hydric status of soils and weighted and index averages of vegetation was tested using field data collected from the transition zones of three southern Rhode Island red maple (Acer rubrum) swamps between 1985 and 1987. Herb layer vegetation exhibited the most clearly defined gradient, correlated best with hydric soil status, and permitted the most precise discrimination between wetland and upland using either averaging procedure. A predominance of facultative shrubs throughout the transition zones obscured gradients in shrub layer scores, and prevented a meaningful correlation with soils. Herb layer weighted averages showed better agreement with hydric soil status than did index averages. Differences between the two averaging methods varied with life form layer, plant importance measure, and site. A 3.0 wetland/upland vegetation breakpoint was reasonable for the herb layer, but too low for trees. Breakpoint evaluation was not possible for the shrub layers because of the absence of consistent trends in scores. Subregional variation in the accuracy of the FWS indicator status for individual plant species and variability in hydric status within a single soil series were identified as important factors affecting the success of soil-vegetation correlations in wetland transition zones.

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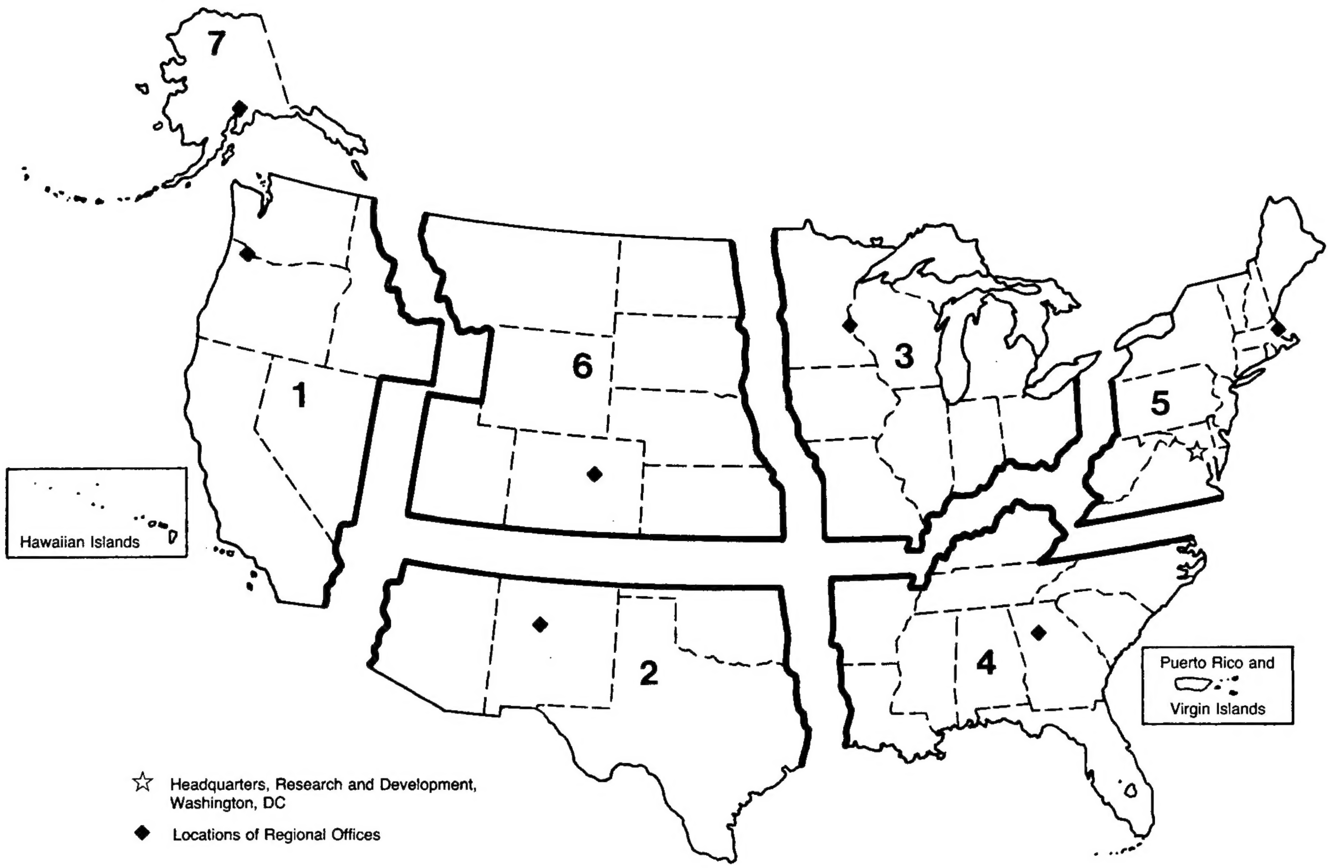

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